Enhanced Die-Down Ball Grid Array and Method for Making the Same

Inventors: Reza-ur Rahman Khan
Sam Ziqun Zhao

Cross-Reference to Other Applications

The following application of common assignee is related to the present application, and is herein incorporated by reference in its entirety:

"Enhanced Die-Up Ball Grid Array and Method for Making the Same," Ser. No. 09/742,366, Attorney Docket No. 1875.0200000, filed December 22, 2000.

Background of the Invention

Field of the Invention

The invention relates generally to the field of integrated circuit (IC) device packaging technology, and more particularly to substrate stiffening and heat spreading techniques in ball grid array (BGA) packages.

Related Art

Integrated circuit (IC) dies are typically mounted in or on a package that is attached to a printed circuit board (PCB). One such type of IC die package is a ball grid array (BGA) package. BGA packages provide for smaller footprints than many other package solutions available today. A BGA package has an array of solder balls located on a bottom external surface of a package substrate. The solder balls are reflowed to attach the package to the PCB. The IC die is mounted to the package substrate. Wire bonds typically couple signals in the IC die to the

substrate. The substrate has internal routing which electrically couples the IC die signals to the solder balls on the bottom substrate surface.

A number of BGA package substrate types exist, including ceramic, plastic, and tape (also known as "flex"). In some BGA package types, a heat spreader/stiffener may be attached to the substrate to provide heat sinking, and to supply planarity and rigidity to the package.

Die-up and die-down BGA package configurations exist. In die-up BGA packages, the IC die is mounted on a top surface of the substrate or heat spreader/stiffener, on a side opposite that of the solder balls. In die-down BGA packages, the IC die is mounted on a bottom surface of the substrate or stiffener, which is the same side as the solder balls.

The tape substrate used in flex BGA packages is typically polyimide, which has very low values of thermal conductivity. Consequently, the IC die is separated from the PCB by the tape substrate thermal barrier. The lack of direct thermal connection from IC die to PCB leads to relatively high resistance to heat transfer from IC die to printed circuit board (theta-jb).

Furthermore, conventional BGA packages are subject to high thermal stresses that result from the heat given off during operation of the mounted IC die. The thermal stresses are primarily imposed on the IC die due to a mismatch of the thermal expansion coefficient (CTE) between the semiconductor die and the stiffener/heat spreader. The thermal expansion coefficient (CTE) of copper typically used for a heat spreader in a tape BGA package is approximately $17.4\times10^{-6}/°C$. For a silicon IC die, the CTE is approximately $2.64\times10^{-6}/°C$. Because of the difference in CTE values, changes in temperature during the BGA package assembly process may lead to high levels of thermal stress. As the IC die size increases for a BGA package, higher stress levels will occur at the interface of the IC die and stiffener/heat spreader. Consequently, cracks often occur on large semiconductor IC dies during the portions of the assembly process following the attachment of the IC die to the stiffener/heat spreader.

Hence, what is needed are BGA packages with improved heat spreading capabilities. What is also needed is a reduction in BGA package thermal stress during the assembly process, to improve packaging yields.

Summary of the Invention

The present invention is directed to an apparatus, system, and method for assembling a ball grid array (BGA) package. In one aspect, a stiffener/heat spreader is provided. A substrate has a first surface and a second surface. The substrate has a central window-shaped aperture that extends through the substrate from the first substrate surface to the second substrate surface. The first substrate surface is attached to a surface of the stiffener/heat spreader. A portion of the stiffener/heat spreader is accessible through the central window-shaped aperture. An IC die has a first surface and a second surface. The first IC die surface is mounted to the accessible portion of the stiffener/heat spreader. A drop-in heat spreader has a surface that is mounted to the second IC die surface.

Further embodiments, features, and advantages of the present inventions, as well as the structure and operation of the various embodiments of the present invention, are described in detail below with reference to the accompanying drawings.

Brief Description of the Figures

The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention.

FIG. 1A illustrates an example die-down BGA package.

FIG. 1B illustrates a heat transfer path from an IC die to a PCB for the example die-down BGA package of FIG. 1A.

FIG. 2A illustrates a cross-sectional view of a BGA package, according to an embodiment of the present invention.

FIG. 2B shows a perspective view of an example drop-in heat spreader, according to an embodiment of the present invention.

FIG. 2C illustrates a bottom view of the BGA package of FIG. 2A, according to an embodiment of the present invention.

FIG. 3A illustrates a cross-sectional view of a BGA package that includes an exemplary drop-in heat spreader, according to an embodiment of the present invention.

FIG. 3B shows a perspective view of the drop-in heat spreader shown in FIG. 3A, according to an embodiment of the present invention.

FIG. 3C illustrate a bottom view of the BGA package of FIG. 3A, with wire bonds from an IC die to a drop-in heat spreader, according to an embodiment of the present invention.

FIG. 3D illustrates a cross-sectional view of BGA package that includes an exemplary drop-in heat spreader with a portion protruding through an encapsulant, according to an embodiment of the present invention

FIG. 4 illustrates a bottom view of an exemplary solder ball arrangement for a BGA package.

FIG. 5 shows an example layer of a substrate, with routing and vias.

FIG. 6 shows a flowchart providing operational steps for assembling one or more embodiments of the present invention.

The present invention is described in the following with reference to the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

Detailed Description of the Preferred Embodiments

Overview

The present invention is directed to a method and system for improving the mechanical, thermal, and electrical performance of BGA packages. The present invention is applicable to all types of BGA substrates, including ceramic, plastic, and tape (flex) BGA packages. Furthermore the present invention is applicable to die-up (cavity-up) and die-down (cavity-down) orientations. Numerous embodiments of the present invention are presented herein.

Preferably, the invention is directed to heat sinking techniques in die-down BGA packaging. A top surface of an IC die is attached to a package stiffener/heat spreader in a die-down BGA package. A drop-in heat spreader is attached to a bottom surface of the IC die. By attaching the top and bottom surfaces of the IC die to heat spreaders, a symmetrical support structure surrounding the IC die is created. This support structure is substantially more symmetrical than the package heat spreader/IC die combination of conventional die-down BGA packages.

An advantage of the configuration of the present invention is a relief of, or a balancing of, stress that may bend an IC die in a conventional die-down BGA package. A conventional die-down BGA package may be considered to be similar to a "bi-metal" system. When temperature rises, the stiffener/heat spreader-to-IC die combination bends in a direction of the material with lower value of CTE; towards the IC die. When temperature is lowered, the heat spreader/IC die combination bends in a direction of the material with higher value of CTE; towards the heat spreader. The present invention described herein substantially forms a "tri-metal" system, with the IC die sandwiched between two heat spreaders. Preferably, the package stiffener/heat spreader is manufactured from the same material as the drop-in heat spreader. In such an arrangement, the package stiffener/heat spreader-to-IC die-to-drop-in heat spreader combination

will not bend significantly with a change of temperature. This is because with temperature changes, both heat spreaders will bend towards or away from the IC die, essentially canceling each other's bending motion.

In a further embodiment, the drop-in heat spreader may be used as either a power plane or a ground plane for the die-down BGA package, to improve die-down BGA package electrical performance. IC die power or ground pads may be wire bound to a drop-in heat spreader attached to the center of the IC die. The drop-in heat spreader may be exposed at the bottom of the die-down BGA package encapsulation. The exposed surface of the drop-in heat spreader may be attached to the PCB. The drop-in heat spreader may be attached to a power or ground potential in the PCB. Such an arrangement may allow for the reduction of power/ground traces and power/ground solder balls, and may lead to shorter distance for supply and return current. These shorter distances may reduce undesired inductances.

Ball grid array package types are described below. Further detail on the above described embodiments, and additional embodiments according to the present invention, are presented below. The embodiments described herein may be combined in any applicable manner, as required by a particular application.

Ball Grid Array (BGA) Package

A ball grid array (BGA) package is used to package and interface an IC die with a printed circuit board (PCB). BGA packages may be used with any type of IC die, and are particularly useful for high speed ICs. In a BGA package, solder pads do not just surround the package periphery, as in chip carrier type packages, but cover the entire bottom package surface in an array configuration. BGA packages are also referred to as pad array carrier (PAC), pad array, land grid array, and pad-grid array packages. BGA packages types are further described in the following paragraphs. For additional description on BGA packages, refer to

Lau, J. H., *Ball Grid Array Technology*, McGraw-Hill, New York, (1995), which is herein incorporated by reference in its entirety.

Die-up and die-down BGA package configurations exist. In die-up BGA packages, the IC die is mounted on a top surface of the substrate or stiffener, which is the side opposite that of the solder balls. In die-down BGA packages, the IC die is mounted on a bottom surface of the substrate or stiffener, which is the same side as the solder balls.

A number of BGA package substrate types exist, including ceramic, plastic (PBGA), and tape (also known as "flex"). FIG. 1A illustrates a tape BGA package 100. Tape BGA package 100 includes an IC die 102, a tape substrate 104, a plurality of solder balls 106, one or more wire bonds 108, a package stiffener/heat spreader 110, and one or more stiffener wire bonds 122. Tape or flex BGA packages are particularly appropriate for large IC dies with large numbers of input and outputs, such as application specific integrated circuits (ASIC) and microprocessors.

Tape substrate 104 is generally made from one or more conductive layers bonded with a dielectric material. For instance, the dielectric material may be made from various substances, such as polyimide tape. The conductive layers are typically made from a metal, or combination of metals, such as copper and aluminum. Trace or routing patterns are made in the conductive layer material. Substrate 104 may be a single-conductive-layer (single-layer) tape, a two-conductive-layer (two-layer) tape, or additional conductive layer tape substrate type. In a two-layer tape, the metal layers sandwich the dielectric layer, such as in a copper-Upilex-copper arrangement. Substrate 104 has a central window-shaped aperture 112 to accommodate IC die 102, as further described below.

Package stiffener/heat spreader 110 may be laminated to substrate 104. Stiffener 110 is typically made from a metal, or combination of metals, such as copper, tin, and aluminum, or may be made from a polymer, for example. Stiffener 110 also acts as a heat sink, and allows for heat spreading in BGA package 100. Stiffener 110 has a central cavity 114 on its bottom surface.

Stiffener 110 may be configured in other ways than shown in FIG. 1A. For example, in other configurations, the bottom surface of stiffener 110 may not include a central cavity 114, and may instead be flat.

IC die 102 is attached directly to stiffener 110, for example, by an epoxy 134. IC die 102 is any type of semiconductor integrated circuit, which has been formed in, and separated from a semiconductor wafer.

One or more wire bonds 108 connect corresponding bond pads 118 on IC die 102 to contact points 120 on substrate 104. Bond pads 118 are coupled to signals internal to IC die 102, including logical signals, and power and ground potentials. Furthermore, one or more wire bonds 122 may connect corresponding bond pads 118 to contact stiffener points 126 on stiffener 110. For instance, stiffener 110 may be used as a power or ground plane.

An epoxy or encapsulant 116 covers IC die 102 and wire bonds 108 and 122 for mechanical and environmental protection.

As described above, BGA package 100 includes an array or plurality of solder balls 106 located on a bottom external surface of package substrate 104. IC die 102 is electrically connected to substrate 104 by one or more wire bonds 108. Wire bonds 108 are electrically connected to solder balls 106 on the bottom surface of substrate 104 through corresponding vias and routing in substrate 104. Vias in substrate 104 can be filled with a conductive material, such as solder, to allow for these connections. Solder balls 106 are attached to substrate 104, and are used to attach BGA package 100 to a PCB.

Note that although wire bonds, such as wire bonds 108, are shown and described herein, IC dies may be mounted and coupled to a substrate with solder balls located on a surface of the IC die, by a process commonly referred to as "C4" or "flip chip" packaging.

FIG. 4 illustrates a bottom view of an exemplary solder ball arrangement for BGA package 100. FIG. 4 shows a 12 by 12 array of solder balls on the bottom surface of substrate 104. Other sized arrays of solder balls are also applicable to the present invention. Solder balls 106 are reflowed to attach BGA

package 100 to a PCB. The PCB may include contact pads to which solder balls 106 are bonded. PCB contact pads are generally made from a metal or combination of metals, such as copper, nickel, tin, and gold. The solder ball array may be organized in any number of ways, according to the requirements of the particular BGA package application.

As described above, the BGA package substrate provides vias and routing on one or more layers to connect contact pads for wire bonds to solder balls attached to the bottom substrate surface. FIG. 5 shows an example layer 502 of substrate 104, with routing and vias, for accomplishing this. A plurality of circular metal ball pads 504 are shown. Metal ball pads 504 may be patterned from a metal layer in substrate 104. As described above, substrate 104 includes central window-shaped aperture 112. Central window-shaped aperture 112 is preferably aligned, but larger than central cavity 114. A plurality of conductive metal traces 506 are shown coupled to metal ball pads 504, and ending in metal fingers 508 near the periphery of central window-shaped aperture 112. In some cases, metal traces 506 may be connected to a power ring 510. A plurality of vias 512 are also shown.

The present invention is applicable to improving thermal and electrical performance in the BGA package types described herein, and further BGA package types. FIG. 1B illustrates a heat transfer path from IC die 102 to a PCB 128 for BGA package 100. BGA package 100 provides a conductive thermal path from an active surface 130 of IC die 102, to a back surface 132 of IC die 102, to a die attach epoxy 134, to stiffener/heat spreader 110, to a tape attach epoxy 136, to substrate 104, to plurality of solder balls 106, to PCB 128. Arrows 138 show directions of heat flow from IC die 102 to PCB 128.

As shown in FIG. 1B, a zone 140 between IC die 102 and PCB 128 does not significantly contribute to heat transfer from IC die 102 to PCB 128, even though providing a relatively short distance between IC die 102 and PCB 128. The lack of heat transfer through zone 140 may be attributed to low conduction

heat transfer coefficients of encapsulant 116 (the "glob top") and an air gap 142 between encapsulant 116 and PCB 128.

As shown in FIG. 1A, stiffener/heat spreader 110 may be used as a ground plane to reduce ground inductance. To further reduce inductance and resistance for power distribution, a separate power ring, such as power ring 510 shown in FIG. 5, must be constructed on substrate 104. Traces have to be added to the routing of substrate 104 to connect between the power ring and corresponding solder ball pads. A disadvantage of this configuration is an increased complexity in the design of substrate 104, and a reduced space for the routing of signal traces in substrate 104. Furthermore, power inductance increases with an increase in trace length in substrate 104.

BGA Package Drop-in Heat Spreader Embodiments According to the Present Invention

Further details of structural and operational implementations of the present invention are described in the following sections. These structural and operational implementations are described herein for illustrative purposes, and are not limiting. The invention as described herein may be implemented in both die-up and die-down BGA package types, as well as in additional IC package types. Furthermore, each of the embodiments presented below are applicable to tape substrate BGA packages, as well as BGA packages with alternative substrate types, including BT, FR4, and ceramic, to name a few. One such package that may include aspects of the present invention is a die-up BGA package, developed by Broadcom Corp., which is located in Irvine, California. The description below is adaptable to these and other package types, as would be understood to persons skilled in the relevant art(s) from the teachings herein.

Features of each of the embodiments presented below may be incorporated into BGA packages independently, or may be combined in any manner in a BGA package, as would be apparent to persons skilled in the relevant art(s) from the teachings herein.

According to embodiments of the present invention, a heat spreader may be used in a BGA package to provide for thermal stress relief to the package, enhance dissipation of heat from the package, and improve package electrical performance. In a preferred embodiment, a drop-in heat spreader is attached to the bottom surface of an IC die in a die-down flex BGA package to provide one or more of these advantages.

FIG. 2A illustrates a cross-sectional view of a die-down flex BGA package 200, according to an embodiment of the present invention. BGA package 200 includes IC die 102, substrate 104, plurality of solder balls 106, one or more wire bonds 108, package stiffener/heat spreader 110, encapsulant 116, one or more stiffener wire bonds 122, and a drop-in heat spreader 202. FIG. 2C illustrates a bottom view of die-down flex BGA package 200, according to an embodiment of the present invention. Encapsulant 116 is not shown in FIG. 2C.

Substrate 104 has a top surface to which a bottom surface of stiffener 110 is mounted. A bottom surface of substrate 104 attaches the plurality of solder balls 106. The plurality of solder balls 106 connect to vias and/or points on the bottom surface of substrate 104 to which signals internal to substrate 104 are routed and exposed. Substrate 104 includes central window-shaped aperture 112 that extends through substrate 104 from the top substrate surface to the bottom substrate surface.

A portion of stiffener/heat spreader 110 is accessible through central window-shaped aperture 112 of substrate 104. In an embodiment, central cavity 114 in stiffener 110 is accessible through window-shaped aperture 112. Central cavity 114 in stiffener 110 coincides with central window-shaped aperture 112 in substrate 104, to accommodate IC die 102. A top surface of IC die 102 is mounted in central cavity 114 of stiffener 110.

In an alternative embodiment, stiffener 110 does not have a central cavity 114, and has a bottom surface that is substantially planar. In an embodiment, a portion of the substantially planar bottom surface of stiffener 110 is accessible

through window-shaped aperture 112. The top surface of IC die 102 is mounted to the accessible portion of the bottom surface of stiffener 110.

In an alternative embodiment, substrate 104 does not have a central window-shaped aperture 112, and is instead continuous. In such an embodiment, the top surface of IC die 102 is mounted to the bottom surface of substrate 104. Stiffener 110 may be coupled to IC die 102 through substrate 104 by one or more solder-filled vias, for instance, for thermal and/or electrical coupling.

One or more wire bonds 108 connect corresponding bond pads 118 on IC die 102 to contact points 120 on substrate 104.

In an embodiment, stiffener 110 is configured to operate as a ground or power plane. For example, one or more stiffener wire bonds 122 connect corresponding ground bond pads 118 to contact points 126 on stiffener 110. Stiffener 110 may be coupled to a ground signal in the PCB through one or more solder balls 106 and vias and/or routing in substrate 104.

As shown in FIG. 2A, a surface of drop-in heat spreader 202 is attached to the top surface (active surface) of IC die 102 using an epoxy 204 or similar substance. Epoxy 204 may be the same substance as encapsulant 116, the same material as epoxy 134, or may be a different substance. Silver filled epoxies may be used for epoxy 204 to enhance heat extraction from IC die 102. Encapsulant 116 may be used for attachment of the drop-in heat spreader to IC die 102. In an embodiment, when encapsulant 116 is used to attach the drop-in heat spreader, the heat spreader is placed on the active surface of the IC die surface before application of the encapsulant.

FIG. 2B shows a perspective view of an example heat spreader 202, according to an embodiment of the present invention. Top surface 206 and bottom surface 208 of heat spreader 202 shown in FIG. 2B are substantially rectangular in shape. Heat spreader 202 includes a circumferential surface 210 that extends around heat spreader 202 between top surface 206 and bottom surface 208. Heat spreader 202 may be configured in other shapes, such as where

top surface 206 and bottom surface 208 of heat spreader 202 are elliptical or round, and other shapes.

The material used for drop-in heat spreader 202 may be one or more metals such as copper or aluminum, for example. Heat spreader 202 may be machined, molded, or otherwise manufactured from these materials. Heat spreader 202 may be made from the same material as stiffener/heat spreader 110. In such an embodiment, stiffener/heat spreader 110 and drop-in heat spreader 202 would have the same thermal expansion coefficient. In such a configuration, the combination of stiffener/heat spreader 110, IC die 102, and drop-in heat spreader 202 will not bend significantly with a change of temperature. As temperature changes, both stiffener 110 and heat spreader 202 will bend towards or away from IC die 102, substantially canceling each other's bend.

In an embodiment, heat spreader 202 is configured to operate as a ground plane or power plane. For example, one or more ground or power wire bonds may be used to connect bond pads on IC die 102 to contact points on heat spreader 202. When bottom surface 208 of heat spreader 202 is exposed after connection to IC die 102, bottom surface 208 can be attached to a PCB using solder, conductive epoxy, or other substances. The PCB connection area is connected to a PCB power or ground plane. Such a configuration may reduce or eliminate power or ground traces on substrate 104, and reduce the number of solder balls attached to substrate 104 that are dedicated to power or ground. This configuration may also lead to shorter current travel lengths, and may reduce inductance and resistance related to BGA package 200. Furthermore, a portion of circumferential surface 210 may also be exposed when bottom surface 208 is exposed.

A drop-in heat spreader may be shaped to provide for easier connection of power or ground wire bonds to the drop-in heat spreader. Furthermore, a portion of the drop-in heat spreader may also protrude through encapsulant 116 for thermal and electrical connection with the PCB. FIG. 3B shows a perspective view of a drop-in heat spreader 300, according to an embodiment of the present

invention. Heat spreader 300 includes a ridge 302. FIG. 3A illustrates a cross-sectional view of BGA package 200 that includes heat spreader 300, according to an embodiment of the present invention. As shown in FIG. 3B, a first surface 304 and second surface 306 of drop-in heat spreader 202 are substantially planar and substantially parallel to each other. A circumferential surface 314 extends around heat spreader 300 between first surface 304 and second surface 306. Ridge 302 extends around at least a portion of the circumference of heat spreader 202, such that an area of surface 306 is greater than that of an area of surface 304. A pedestal 312 of heat spreader 300 is formed by a portion of circumferential surface 314 of heat spreader 300 between ridge 302 and first surface 304.

Ridge 302 provides a convenient connection point for wire bonds. FIG. 3C illustrates a bottom view of BGA package 200, with wire bonds from IC die 102 to heat spreader 300, according to an embodiment of the present invention. For example, one or more ground wire bonds 308 connect corresponding ground bond pads 118 on IC die 102 to contact points 310 on heat spreader 300. As shown in FIG. 3A, contact points 310 may be located on ridge 302 of heat spreader 300.

As shown in FIGS. 2A and 3A, heat spreaders 202 and 300 may be smaller in area than the bottom surface of IC die 102. Alternative sizes for heat spreaders 202 and 300 are also applicable to the present invention, including sizes equal to the area of IC die 102, or larger areas. Heat spreaders 202 and 300 are shaped and configured to spread heat from IC die 102, as is required by the particular application. For example, by maximizing the size of heat spreader 202 and 300, such that edges of heat spreaders 202 and 300 are close to wire bond pads on IC die 102, self-inductance due to a reduced wire bond length may be minimized.

An encapsulant may be used to encapsulate the IC die and at least a portion of the drop-in heat spreader. In FIG. 2A, IC die 102 and drop-in heat spreader 202 are completely encapsulated by encapsulant 116. In an alternative embodiment, such as shown in FIG. 3A, a portion of drop-in heat spreader 300

(surface 304) is exposed through encapsulant 116. A portion of the circumferential surface of heat spreader 300 between surface 304 and surface 306 may also be exposed through encapsulant 116. For example, all or a portion of pedestal 312 may protrude through encapsulant 116, as shown in FIG. 3D. As described above, when exposed, the exposed surface of the drop-in heat spreader may be configured to be attached to a PCB. For instance, the exposed surface may be plated with solder. By exposing a surface of the drop-in heat spreader for attachment to a PCB, a greater transfer of heat from the BGA package may be obtained.

By attaching drop-in heat spreader 202 or 300 to the top surface of IC die 102, the mechanical structure of BGA package 200 becomes more symmetrical in its center region. Thermal stress at the interface of IC die 102 and stiffener 110 is substantially released or altered by the drop-in heat spreader. Deformation caused by thermal stress is substantially reduced through the use of a drop-in heat spreader, such as heat spreader 202 or 300. Drop-in heat spreaders 202 and 300 allow for even larger sizes of IC die 102 and greater I/O counts by providing for greater heat spreading capacity in BGA package 200.

FIG. 6 shows a flowchart 600 providing operational steps for assembling one or more embodiments of the present invention. For example, the steps of flowchart may be used to assemble BGA package 200. The steps of FIG. 6 do not necessarily have to occur in the order shown, as will be apparent to persons skilled in the relevant art(s) based on the teachings herein. Other structural embodiments will be apparent to persons skilled in the relevant art(s) based on the following discussion. These steps are described in detail below.

Flowchart 600 begins with step 602. In step 602, a substrate is provided that has a first surface and a second surface, wherein the substrate has a central window-shaped aperture that extends through the substrate from the first substrate surface to the second substrate surface. For example, the substrate is tape substrate 104, or another substrate type suitable for a BGA package. The central window-shaped aperture is window-shaped aperture 112.

In step 604, a stiffener/heat spreader is provided. For example, the stiffener is stiffener/heat spreader 110.

In step 606, a surface of the stiffener/heat spreader is attached to the first substrate surface, wherein a portion of the stiffener/heat spreader is accessible through the central window-shaped aperture. For example, a surface of stiffener 110 is attached to a surface of substrate 104. In an alternative embodiment, substrate 104 does not have a central window-shaped aperture, but is continuous.

In step 608, a first surface of an IC die is mounted to the accessible portion of the stiffener/heat spreader. For example, the IC die is IC die 102, which is mounted to stiffener 110. In an alternative embodiment, when substrate 104 is continuous, the first surface of IC die 102 is mounted to substrate 104.

In step 610, a surface of a drop-in heat spreader is mounted to a second surface of the IC die. For example, the drop-in heat spreader may be heat spreader 202 or 300, which is mounted with epoxy 204 or other attachment means to the bottom surface of IC die 102. Heat spreader 202 or 300 typically is mounted to the center of the bottom surface of IC die 102, and covers less than the entire bottom surface of IC die 102. For instance, the smaller area of heat spreader 202 or 300 allows for bond pads 118 to be exposed on the bottom surface of IC die 102 for wire bond connections. In alternative embodiments, heat spreader 202 or 300 is of the same size, or comprises a larger area than the upper surface of IC die 102.

A benefit of performing the steps of flowchart 600 is that the heat spreader relieves thermal stress at an interface of the IC die and the first stiffener surface. Further benefits may include an enhancement of heat dissipation from the BGA package, and an improvement in BGA package electrical performance.

In an embodiment, flowchart 600 comprises the additional step where a plurality of solder balls are attached to the second substrate surface. For example, the plurality of solder balls are plurality of solder balls 106, which connect to vias and/or solder ball pads on the bottom surface of substrate 104. The solder balls may be arranged on the bottom surface of substrate 104 as shown in FIG. 4, for

example, or in alternative arrangements. The solder balls are used to attach a BGA package to a PCB.

In an embodiment, the second IC die surface includes a contact pad. For example, the contact pad may be contact pad 118. Flowchart 600 may further comprise the step where the contact pad is coupled to the drop-in heat spreader with a wire bond. For example, the wire bond may be wire bond 108, 122, or 308. In an embodiment, the contact pad is a ground contact pad. Flowchart 600 may comprise the additional step where the ground contact pad is coupled to the drop-in heat spreader with the wire bond, wherein the drop-in heat spreader operates as a ground plane.

In an embodiment, step 610 comprises the step where a drop-in heat spreader is provided that has a first planar surface, wherein said drop-in heat spreader has a second planar surface, wherein said first and said second planar surfaces are substantially parallel to each other, wherein said drop-in heat spreader has a ridge around at least a portion of its circumference such that an area of said first planar surface is greater than that of said second planar surface. For example, the ridge is ridge 302. In an embodiment, flowchart 600 comprises the additional step where the wire bond is attached to the ridge of the drop-in heat spreader. For example, the wire bond is wire bond 308.

In an embodiment, flowchart 600 comprises the additional step where a second surface of the drop-in heat spreader is configured to be attached to a printed circuit board. For example, the bottom surface of the heat spreader is exposed, and may be plated with solder.

In an embodiment, flowchart 600 comprises the additional step where a central cavity is formed in the stiffener/heat spreader surface, wherein the central cavity forms at least a portion of the accessible portion of the stiffener/heat spreader. For example, the central cavity is central cavity 114. In an embodiment, step 608 comprises the step where the IC die is mounted in the central cavity.

In an embodiment, step 610 comprises the step where a drop-in heat spreader is provided that is substantially planar, wherein the accessible portion of the stiffener/heat spreader is centrally located on the substantially planar stiffener/heat spreader surface.

In an embodiment, step 608 comprises the step where the IC die first surface is mounted to the stiffener/heat spreader with a first epoxy, wherein the drop-in heat spreader is mounted to the IC die with a second epoxy. For example, the first epoxy is epoxy 134, and the second epoxy is epoxy 204.

In an embodiment, an area of the second IC die surface is greater than an area of a surface of the drop-in heat spreader. Flowchart 600 may include the additional step where the drop-in heat spreader is configured to mount to the center of the second IC die surface.

In an embodiment, flowchart 600 comprises the additional step where the IC die and the drop-in heat spreader are encapsulated. For instance, IC die 102, heat spreader 202 or 300, and wire bond 108 are encapsulated by a molding compound or epoxy, shown as encapsulant 116. In a first embodiment, the IC die and the drop-in heat spreader are encapsulated where neither are exposed, as shown in FIG. 2A, for example. In a second embodiment, a surface of the drop-in heat spreader is exposed, as shown in FIG. 3A, for example. In a third embodiment, a portion of circumferential surface of the drop-in heat spreader is exposed and protrudes through the bottom surface of encapsulant 116, as shown in FIG. 3D, for example.

In an embodiment, step 602 comprises the step where a tape substrate is provided. For example, substrate 104 may be a tape substrate.

In an embodiment, flowchart 600 comprises the additional step where a thermal expansion coefficient of the stiffener/heat spreader is matched to the thermal expansion coefficient of the drop-in heat spreader. For example, stiffener 110 and heat spreader 202 or 300 are constructed from the same material, such that their thermal expansion coefficients are substantially matched.

Conclusion

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.